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MUSCULOSKELETAL AND MEDICAL MORBIDITY ASSOCIATED WITH RIGOROUS PHYSICAL TRAINING

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Musculoskeletal and Medical Morbidity Associated with Rigorous Physical Training

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Abstract: In a prospective, epidemiological study, we describe the distribution and rates of medical conditions and musculoskeletal injuries suffered during training by U.S. Navy SEAL (Sea-Air-Land) Special Warfare trainees. The subjects were consecutive classes of candidates, healthy males, aged 18 to 31, contributing 482 trainee-months at risk. They were undergoing a physically demanding 25-week Naval Special Warfare Center indoctrination training during 1991 in Coronado, California. The main outcome measures were training-related medical conditions and musculoskeletal injuries resulting in a visit to the outpatient medical clinic. Combined medical conditions and musculoskeletal injuries occurred at a rate of 61.4 cases per 100 trainee-months at risk. Visits were nearly evenly split between medical conditions and musculoskeletal injuries. Respiratory complaints accounted for almost half of the medical conditions; overuse injuries (primarily, iliotibial band syndrome, patellofemoral syndrome, and stress fracture) accounted for 90% of the musculoskeletal injuries. We conclude that strenuous, sustained physical training results in a high incidence of medical conditions and musculoskeletal injury in trainees. Given this high morbidity, recommending limits on the amount and intensity of exercise seems prudent. Further research should examine the etiology, predisposing factors, therapy, and prevention of exercise-induced medical conditions and injuries. **Key Words:** Physical fitness—Epidemiology—Overuse injury—Morbidity—Physical training—Musculoskeletal. *Clin J Sport Med* 1993;3:(4):229–34.

Documented multiple health benefits from regular physical activity are the prevention and management of coronary heart disease, diabetes mellitus, osteoporosis, obesity, and mental health problems (26). Regular physical activity has been promoted as a necessary and important component of disease prevention, health promotion, and improved quality of life (2,7,17,26). Yet, significant gaps in knowledge remain concerning the short-term morbidity associated with physical activity.

Exercise-related soft-tissue injury rates and medical conditions connected to exercise have been reported in select populations, but the studies often suffer from methodological difficulties. Rate comparisons are difficult between studies, usually because only the cumulative frequency of injuries are reported over variable training periods (4,9,13,19). The diagnoses are often grouped into nonspecific categories such as knee injuries, sprains, and tendinitis, which further complicate direct comparisons. In retrospective studies using medical record review to obtain data, the population at risk is difficult to ascertain. In some such cases, rates cannot be calculated.

We investigated outpatient medical conditions and musculoskeletal injuries associated with an ex-

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tremely rigorous, sustained physical training program. The U.S. Navy SEALs (Sea-Air-Land) comprise an elite group of Naval Special Warfare personnel whose origins date back to 1943. At that time, the first group of volunteers from the Naval Construction Battalions fought during the invasion of Sicily. Since then, SEALs have played vital roles in unconventional warfare, counter-guerrilla warfare, and clandestine operations in maritime and riverine environments. Mission completion depends on the highest level of physical and mental stamina. These requirements dictate that initial training of prospective SEALs be among the most difficult and physically demanding military training programs in the world (1).

Favorable research characteristics of the SEAL trainee population include standardized training regimens, complete participation in all events, and a well-delineated population. This is in sharp contrast to individual or team sport populations where player exposure to physical stress varies depending on the degree of player participation and the specific position played (12,20,28). Conversely, the closed environment of military training allows accurate determination of population-at-risk.

We determined the rate of medical conditions and musculoskeletal injuries among U.S. Navy SEAL trainees at the Naval Special Warfare Center, Coronado, California, between April and June 1991. We prospectively examined the distribution and rates of cases presenting to the clinic by specific International Classification of Disease (ICD-9) diagnosis (25).

METHODS

Study group

All subjects were SEAL candidates training between April and June, 1991. Eligibility for selection to training included the following criteria: male, between the ages of 18 and 31, passing a screening physical fitness test, and completing a combat swimmer physical examination.

Prior to official training, all candidates engage in structured and mandatory fitness preparation for a period of 2 to 7 weeks, varying according to reporting date and degree of fitness on arrival. Formal training continues for 25 weeks and consists of three instructional phases that emphasize different strengths. Phase 1 involves 9 weeks of physical conditioning that requires pool and ocean swims of up to 2 miles, 4-mile timed runs, obstacle course, and inflatable raft seamanship. The sixth week of this phase, known as "Hell Week," consists of five and a half virtually sleepless days of nonstop training. Because of the nature of training during this week, injuries are treated by medical personnel in the field who follow the trainees for that purpose. Consequently, data from this week were inaccessible for our study.

Conditioning continues during the second and third phases but has a different focus. Phase 2, which is 7 weeks in duration, emphasizes basic combat diving and swimming. The third and final phase of formal training involves 9 weeks of land warfare, including activities like rapelling. The final 5 weeks of this phase were spent off-site. Any diagnoses made during this period were not recorded nor were population days at risk counted for our study. During all three phases, physical training intensified progressively. In summary, individuals were at risk and under observation (for study purposes) for 22 to 27 weeks.

Data collection

We used a specially designed computer-based data collection system to record all patient encounters at the medical clinic during the study period. The software program featured user-friendly pull-down menus, preset defaults, and memory search features. A personal computer located at the clinic was linked via modem to a central VAX computer where the actual-time data entry was monitored closely by research personnel to ensure completeness.

We collected the following information on all patients who presented to the clinic for care: name, social security number, sex, date of birth, race, rate/rank, date reported to training, date of encounter, current phase of training, new or follow-up visit, and diagnosis. One of two physicians confirmed all diagnoses, which were recorded by specific ICD-9 code.

Injury codes were organized in the computer software by anatomical location—such as knee, shoulder, foot—on pull-down menus. If the specific diagnosis could not be found on the menu, a special code was entered and a comment provided in free text. Research staff would then classify the diagnosis by referring to the ICD-9 text and, where appropriate, add the new ICD-9 code and descriptive text to the menu. We displayed daily patient logs locally and at the research facility to help ensure accuracy and completeness.

We obtained counts of the population at risk used to calculate incidence rates from daily census figures provided by the Naval Special Warfare Center personnel department. The population at risk included only those trainees who were physically located at the base and who would present to the clinic if injured.

Injury was defined as any complaint or disability that developed during the study period and required a clinic visit, involved the musculoskeletal system, resulted from training, and was assigned an injury-related ICD-9 code.

Overuse injury, a subset of musculoskeletal injury, was defined as nonacute musculoskeletal injuries sustained over a period of time. Collaboration with clinical medical personnel who understand the SEAL training experience and etiology of injuries

during training consulted in classification of specific ICD-9 codes as overuse injuries.

Medical conditions were defined, similar to musculoskeletal injury, as any complaint that required a clinic visit and was assigned a medically related diagnostic code. The *International Classification of Disease, Clinical Modification,* 9th edition code book describes the criteria used to classify each specific injury or medical condition (25).

Analysis of data

We summarized demographic characteristics of the population and grouped diagnoses into one of two categories: medical conditions (noninjury) and musculoskeletal injuries. Incidence rates were expressed as the number of cases per 100 trainee-months at risk.

RESULTS

SEAL trainees were exclusively male, predominantly Caucasian and enlisted, and between the ages of 18 and 31.

During the study period, 482 trainee-months at risk and 296 cases were accumulated (Table 1). One hundred trainee-months can be interpreted as the equivalent of 100 troops training for 30 days. Combined medical conditions and musculoskeletal injuries occurred at a rate of 61.4 cases per 100 trainee-months at risk. Visits were nearly evenly split between medical conditions (31.7 cases per 100 trainee-months) and musculoskeletal injuries (29.7 cases per 100 trainee-months).

Respiratory conditions accounted for nearly half (14.7 cases per 100 trainee-months) of the medical disorder cases (Table 2). Acute bronchitis, common cold, strep throat, and sinusitis were the leading diagnoses in this category.

In the grouping of the 143 musculoskeletal injuries by anatomical location, over three-quarters involved the lower limb (Table 3). Iliotibial band syndrome, patellofemoral syndrome, and stress fracture occurred most frequently among specific injury diagnoses. Overuse injury accounted for >90% of musculoskeletal injury, with most cases occurring at the knee (Table 4).

TABLE 1. *Incidence[a] of musculoskeletal and medical disorders among SEAL trainees at NAVSPECWAR, Coronado, April–June 1991*

Disorder	Frequency	Incidence[a] (new cases/100 trainee-months)
Total	296	61.4
Medical (noninjuries)	153	31.7
Musculoskeletal injuries	143	29.7

SEAL, Sea-Air-Land; NAVSPECWAR, Naval Special Warfare Center.

[a] Incidence of new cases/100 trainee-months accumulated over 482 trainee-months.

TABLE 2. *Incidence[a] of medical disorders (exclusive of musculoskeletal injuries) among SEAL trainees at NAVSPECWAR, Coronado, April–June 1991*

Disorder	ICD-9 Code	Frequency	Incidence[a]
Medical conditions		153	31.7
Respiratory		71	14.7
Bronchitis	49000	27	5.6
Common cold	46000	21	4.4
Strep throat	03400	8	1.6
Sinusitis	46100	6	1.2
Pharyngitis/sore throat	46200	4	0.8
Influenza	48710	2	0.4
Tonsillitis	46300	1	0.2
Upper respiratory infection	46590	1	0.2
Pneumonia	48600	1	0.2
Gastrointestinal		28	5.8
Gastroenteritis	55890	21	4.4
Diarrhea, functional	56450	2	0.4
Hemorrhoids	45530	1	0.2
Ulcer, gastric	53190	1	0.2
Gastritis	53540	1	0.2
Cholecystitis	57500	1	0.2
Abdominal pain	78900	1	0.2
Head, ear, nose, and throat		23	4.8
Otitis externa	38010	5	1.0
Otitis serous	38100	4	0.8
Eustachian tube dysfunction	38181	4	0.8
Otitis media	38200	3	0.6
Eye infection	36000	1	0.2
Ear impaction	38040	1	0.2
Tympanic membrane rupture	38420	1	0.2
Conduction disorder	42690	1	0.2
Syncopal episode	78020	1	0.2
Headache	78400	1	0.2
Nosebleed	78470	1	0.2
Dermatological		4	0.8
Wart	07810	1	0.2
Impetigo	68400	1	0.2
Ingrown toenail	70300	1	0.2
Folliculitis	70480	1	0.2
Urogenital		3	0.6
Genital herpes	05410	1	0.2
Gonorrhea	09800	1	0.2
Pediculosis pubis	13290	1	0.2
Other		22	4.6
Patient not seen	V6430	11	2.3
Administrative encounters	V6890	4	0.8
Consultation	V6590	3	0.6
Hypothermia	99160	1	0.2
Typhoid shot	V0310	1	0.2
Chest x-ray reading	V7250	1	0.2
Skin test for tuberculosis	V7410	1	0.2

SEAL, Sea-Air-Land; NAVSPECWAR, Naval Special Warfare Center; ICD-9, International Classification of Disease.

[a] Incidence expressed as number of cases per 100 trainee-months at risk.

DISCUSSION

Although increasing physical activity has many beneficial long-term health effects, it can also result in significant short-term morbidity. Musculoskeletal injury (especially overuse injury) and medical conditions (especially involving the respiratory system) occurred at very high rates. The lack of diagnostic specificity in previous studies made direct comparison of rates difficult; but it is apparent that the morbidity rates are higher in this population than in most others reported (4,5,9,13).

Although this study was not designed to assess the etiology of these clinical conditions, attributing

TABLE 3. *Incidence[a] of musculoskeletal disorders among SEAL trainees at NAVSPECWAR, Coronado, April–June 1991*

Disorder	ICD-9 Code	Frequency	Incidence[a]
Musculoskeletal		143	29.7
Lower limb		112	23.2
Ankle/foot		34	6.0
Sprain/strain, Achilles	84509	5	1.0
Tendinitis, ant/post tibialis	72672	5	1.0
Tendinitis/bursitis, Achilles	72671	4	0.8
Blister, noninfected	91720	3	0.6
Blister, infected	91730	3	0.6
Tendinitis/bursitis, peroneal	72679	3	0.6
Sprain/strain, foot, cuboid	84519	2	0.4
Cellulitis, foot	68270	1	0.2
Tenosynovitis	72706	1	0.2
Bunion/bunionette	72710	1	0.2
Plantar fasciitis	72871	1	0.2
Stress fracture	73310	1	0.2
Pes planus	73400	1	0.2
Sprain, ankle, unspecified	84500	1	0.2
Sprain, ankle, deltoid	84501	1	0.2
Strain/sprain, foot, other	84510	1	0.2
Lower leg		16	3.3
Stress fracture	73310	11	2.3
Periostitis	73350	3	0.6
Sprain/strain, lower leg	84490	1	0.2
Abrasion/friction burn	91900	1	0.2
Knee		49	10.2
Iliotibial band syndrome	72662	21	4.4
Patellofemoral syndrome	71770	16	3.3
Contusion, knee	92411	5	1.0
Sprain, lateral collateral	84400	2	0.4
Tendinitis, patella	72664	1	0.2
Tendinitis, knee	72709	1	0.2
Periostitis	73350	1	0.2
Sprain, medial collateral	84410	1	0.2
Sprain, cruciate	84420	1	0.2
Hip/thigh		13	2.7
Sprain/strain, hip	84380	7	1.4
Stress fracture	73310	3	0.6
Cellulitis, hip and thigh	68260	1	0.2
Hamstring pull	84300	1	0.2
Contusion, thigh	92400	1	0.2
Upper limb		16	3.3
Wrist/hand		1	0.2
Strain/sprain, IP joint	84213	1	0.2
Elbow/forearm		7	1.4
Tendinitis, elbow	72639	5	1.0
Epicondylitis	72632	2	0.4
Shoulder/arm		8	1.6
Sprain/strain, biceps	84080	3	0.6
Shoulder instability	71881	1	0.2
Tendinitis, rotator cuff (RC)	72610	1	0.2
Subacromial bursitis	72619	1	0.2
Sprain/strain/tear, RC	84040	1	0.2
Contusion, shoulder	92300	1	0.2
Trunk		15	3.1
Back/pelvis		9	1.9
Low back sprain	84690	7	1.4
Strain/sprain, pelvis	84880	1	0.2
Contusion, back	92230	1	0.2
Chest		6	1.2
Costochondritis	73390	3	0.6
Contusion	92210	3	0.6

SEAL, Sea-Air-Land; NAVSPECWAR, Naval Special Warfare Center.

[a] Incidence expressed as number of cases per 100 trainee-months at risk.

the higher rates to the extreme physical activity seems appropriate. Other studies confirm this relationship: For example, among triathletes, a group known for their intense and rigorous training habits, overuse injury rates up to 86% of participants have been reported (16).

Overuse injury accounted for >90% of all musculoskeletal injury. The distribution of overuse injuries observed in this study was similar to that seen among civilian runners. The rank order of specific musculoskeletal injuries observed is generally consistent with patterns described by other athletic and military investigators, although iliotibial band syndrome (ITBS) occurred more frequently in our subjects (4,13,22,23). Conceivably, the familiarity of SEAL clinic providers with ITBS and other musculoskeletal injuries may have influenced diagnosis and, consequently, rates of injury. However, the rates of injury are not felt to be artifically high, and diagnostic procedures agree with accepted standards in sports medicine.

Overuse injuries are caused by repetitive microscopic trauma or overloading of musculoskeletal structures that leads to inflammation and secondary pain (20). These forces individually are insufficient to cause injury, but the cumulative effect exceeds the adaptive capacity of the body (23). For example, while running, there are ~1000 to 1200 foot strikes per mile each at 1.5 to 3 times bodyweight, putting tremendous cumulative stress on the musculoskeletal system (23). Several factors believed to contribute to overuse injury include persistent high intensity training and sudden increases in intensity (23). When an injury or re-injury cycle has been established, symptoms often do not resolve until the cycle is broken by resting the injured extremity.

Known predisposing factors for overuse injury prevalent among SEAL trainees include progressively increased running mileage, changes in running surface, running on uneven surfaces or in soft sand, and running in boots (8). Participation in training events for SEAL trainees is mandatory. Conversely, distance runners have the luxury of longer recovery periods, rest breaks, and individually varying training intensity. SEAL trainees are

TABLE 4. *Incidence[a] of overuse injuries by anatomical location among SEAL trainees at NAVSPECWAR, Coronado, April–June 1991*

Disorder	Frequency	Incidence[a]
Total overuse injuries	129	26.8
Knee	44	9.1
Ankle/foot	33	6.8
Lower leg	15	3.1
Hip/thigh	11	2.3
Back	8	1.6
Shoulder/arm	7	1.4
Elbow/forearm	7	1.4
Chest	3	0.6
Wrist/hand	1	0.2

SEAL, Sea-Air-Land; NAVSPECWAR, Naval Special Warfare Center.

[a] Incidence expressed as number of cases per 100 trainee-months at risk.

known to continue training in spite of injuries ("play hurt"), possibly exacerbating minor subclinical injuries (14,17). Experts believe risk factors for injury might also include: prior physical conditioning, proper warm-up and stretching, race, body composition, history of previous injury, nutrition, temporal aspects of injury in relation to training cycle, type of activity or training situation precipitating a particular injury, and anatomical factors (e.g., Q angle, pes cavus/planus, leg length discrepancies) (9,10,15,21,22,24,27).

Rates of medical conditions compared to musculoskeletal injury were particularly interesting. Respiratory conditions accounted for half of the medical conditions—and occurred at a rate more than double the 1987 U.S. incidence rate for all acute respiratory conditions (14.7 versus 6.7 cases per 100 person months) (18).

High rates of respiratory illness are known to occur with overcrowding, cigarette smoking (including passive smoking), colder monthly temperatures, progressively younger age, and among females (18). The SEAL trainees lived and trained in close quarters, smoked infrequently (not permitted during training), trained in San Diego during late spring/early summer (warm climate), averaged 20 years of age, and were male. Although this study was not designed to weigh the contribution of these combined factors, provide a nontraining comparison group, nor examine medical conditions, the rate observed seems so remarkable that it deserves further attention.

Possible explanations of the higher rate of respiratory illness include the stressful environment of training and the intense level of sustained exercise. As measured by the Daily Hassle Scale, a tool used by other researchers to examine the effects of stress on individuals, the high-stress groups have been shown to have significantly more episodes and more symptom-days than low stress groups in some studies (6). While low-intensity exercise appears to be beneficial for the immune system, high intensity and long duration exercise can result in immunosuppression and adverse effects on immune function (3). Overtraining may lead to temporary susceptibility to infection (11).

Throughout this study, the computer-based data collection system proved to be highly flexible and dependable, increasing our confidence in the reliability of the findings. We used actual-time entry of specific diagnoses, eliminating many of the classification biases inherent in studies using chart review methods to obtain data.

The intense physical training and progressive physical demands involved in SEAL training probably exceed those of almost any other group (1). We conclude that exercise-related morbidity in this group was substantial, probably representing the quantitative extreme in comparison to other exercising groups. Given the high morbidity shown to be associated with extreme physical-conditioning activity, recommending limits on the amount and intensity of exercise seems prudent.

Application of epidemiological methods, as in this study, provide the logic and methods to quantitatively identify factors contributing to the risk of illness and injury. Presently, risk factors of musculoskeletal injury and medical conditions during intense physical activity are not well defined. These factors need to be systematically delineated for primary prevention to be possible. To better understand and minimize the negative impact of exercise-related morbidity, further research should examine the etiology, predisposing factors, therapy, and prevention of exercise-induced medical conditions and injuries.

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13. ABSTRACT *(Maximum 200 words)*

The distribution and rates of medical conditions and musculoskeletal injuries suffered during training by U.S. Navy SEAL Special Forces trainees were described in a prospective, descriptive epidemiological study. We studied consecutive classes of candidates undergoing the physically-demanding 25-week Navy Special Warfare indoctrination training during Spring 1991 in Coronado, CA. Healthy males, ages 19 to 31, contributed 482 trainee-months at risk. Combined medical conditions and musculoskeletal injuries occurred at a rate of 61.4 cases per 100 trainee-months at risk. Visits were nearly evenly split between medical conditions (31.7 cases/100 trainee-months) and musculoskeletal injuries (29.7 cases/100 trainee-months). Respiratory complaints accounted for almost half (14.7 cases/100 trainee-months) of the medical conditions, while overuse injuries (primarily iliotibial band syndrome, patellofemoral syndrome, and stress fracture) accounted for 90% of the musculoskeletal injuries.

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